THE WEATHER AND CIRCULATION OF JANUARY 1951

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CIRCULATION FEATURES

The circulation pattern at the 700-mb. level during January 1951 shown in figure 1 differed only slightly from the long period "normal" for January. For the first time since this series of articles was initiated a year ago, the monthly mean 700-mb. height anomaly did not exceed 220 feet in absolute magnitude anywhere in the Northern Hemisphere. In the North American region January height anomalies as small as those observed this year have occurred only once previously (1939) in the past 20 years. As a result, the waves in the westerlies were in approximately their normal location, with principal troughs located in the western Pacific and eastern North America, low latitude troughs in the Mediterranean and the Gulf of California, and ridges in western Canada, the eastern Atlantic, and the southeast Pacific. The outstanding abnormalities in the hemispheric circulation were the High in the Bering Sea, the Low in the Gulf of Alaska, the positive height anomaly center south of Newfoundland, and the negative height anomaly in northern Eurasia.

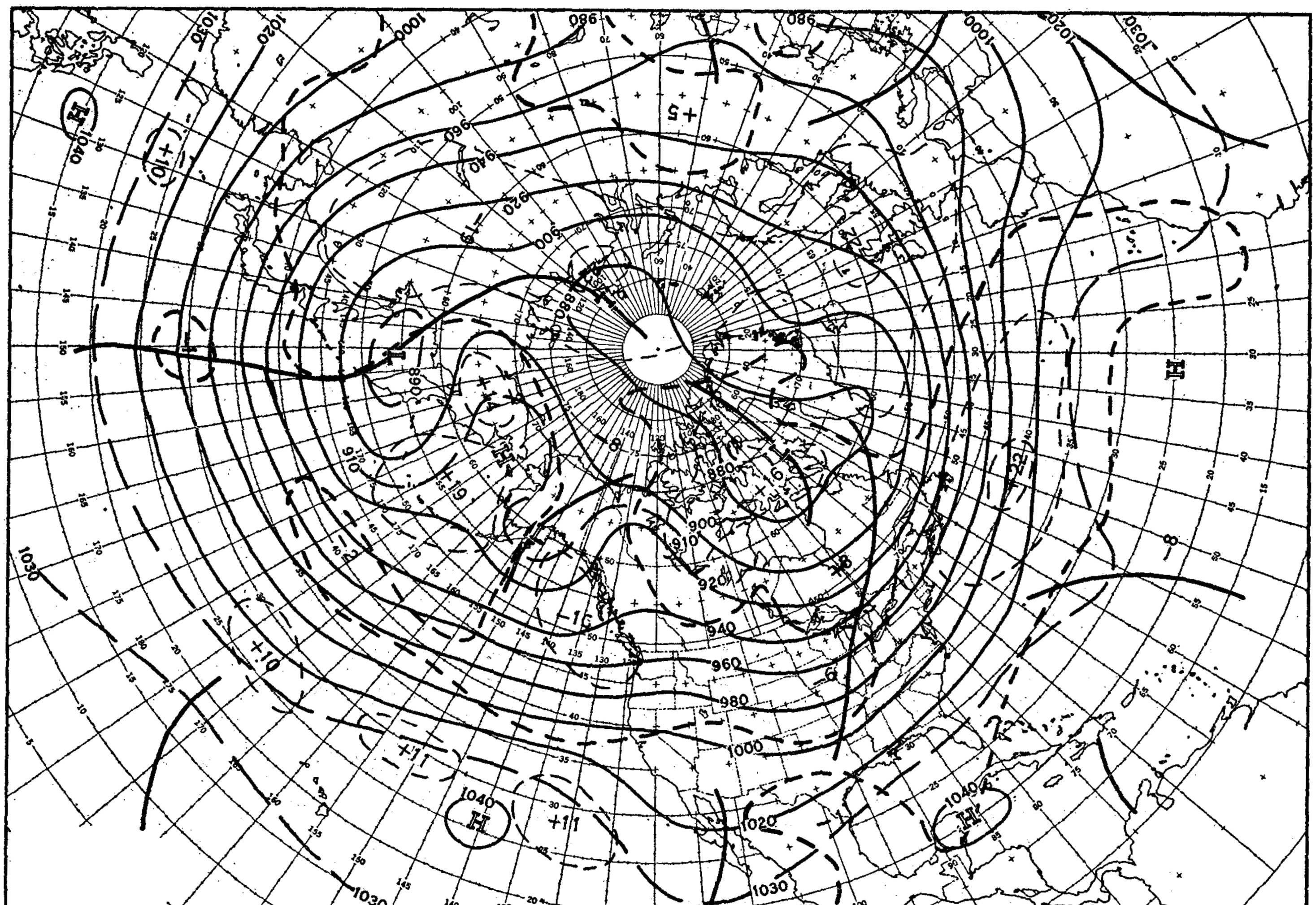

FIGURE 1.—Mean 700-mb. chart for the 30-day period January 2-31, 1951. Contours at 200-ft. intervals are shown by solid lines, intermediate contours by lines with long dashes, and 700-mb. height departure from normal at 100-ft. intervals by lines with short dashes with the zero isopleth heavier. Anomaly centers and contours are labeled in tens of feet, Minimum latitude trough locations are shown by heavy solid lines.

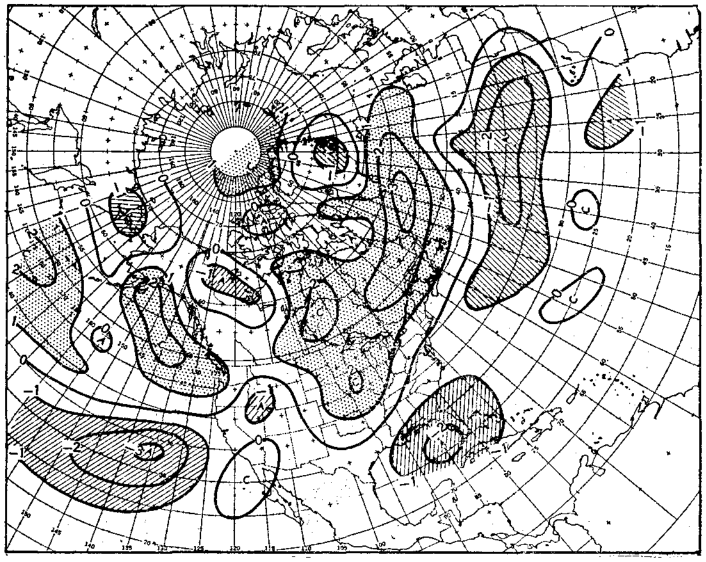

Figure 2.—Vertical component of mean relative geostrophic vorticity at 700 mb. for the 30-day period January 2–31, 1951. Areas with cyclonic vorticity in excess of 1×10^{-5} per second are stippled and labeled C at the center; areas with anticyclonic vorticity less than -1×10^{-5} per second are cross hatched and labeled A at the center.

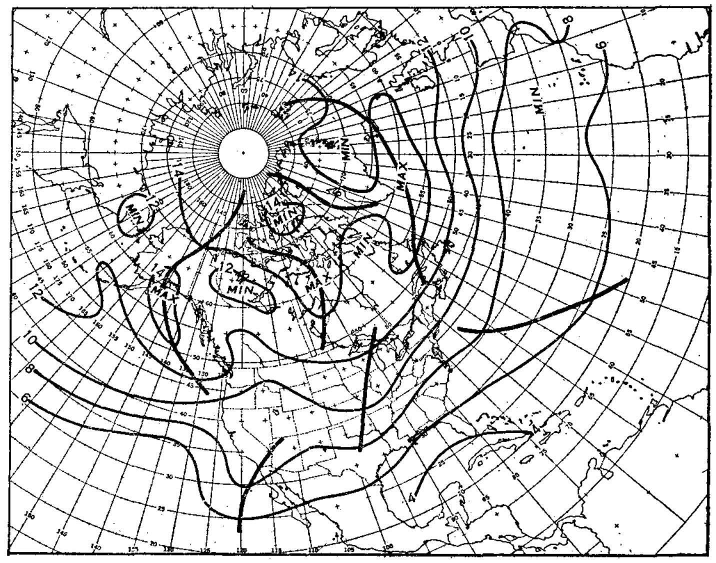

Figure 3.—Vertical component of mean absolute geostrophic vorticity at 700 mb. for the 30-day period January 2–31, 1951. Isopleths at intervals of 2×10^{-5} per second are shown by solid lines and maximum latitude ridge locations by heavy solid lines. Centers of maximum and minimum absolute vorticity are labeled MAX and MIN respectively.

In order to throw additional light on this month's circulation, figure 1 was supplemented by two charts showing the geographical distribution of monthly mean geostrophic vorticity at the 700-mb. level. Figure 2 gives the vertical component of the mean vorticity relative to the earth's surface, computed at standard 5° intersections of latitude and longitude from the 700-mb. contour field (fig. 1).[1] The vorticity values are considerably smaller in magnitude than corresponding values computed from daily sea level maps [1], nevertheless a well-defined pattern is evident. The influence of wind shear is indicated by the fact that cyclonic vorticity generally prevails north of the latitude of the mean 700-mb. jet stream (40°–45° N.) and anticyclonic vorticity to the south. The effect of contour curvature is also noticeable. As one would expect, regions of cyclonic vorticity in figure 2 generally correspond with regions of cyclonic curvature in figure 1, while anticyclonic vorticity prevails in regions of anticyclonic curvature. Even more striking is the close connection between relative vorticity at 700 mb. and isobar curvature at sea level, as can be seen by comparing figure 2 with Chart XI[2]. Centers of anticyclonic vorticity at 700 mb. are superimposed on centers of high pressure at sea level in the southeast Pacific, northwest Canada, Great Basin of the United States, and Azores Islands, while areas of cyclonic vorticity and sharp pressure troughs almost coincide in the western Aleutians, Gulf of Alaska, Hudson Bay, Mississippi Valley, and North Atlantic. Thus the field of relative vorticity at 700 mb. appears to be a good index of the mean sea level circulation This is particularly true of monthly mean maps where quasi-barotropic conditions usually prevail.

Figure 3 gives the vertical component of the absolute geostrophic vorticity for the month of January 1951. It was prepared by simply adding the Coriolis parameter to values of the relative vorticity computed for figure 2. As a result the absolute vorticity generally increases in magnitude with increasing latitude and the isopleth pattern is primarily sinusoidal in character. The lines of absolute vorticity in figure 3 parallel the contours in figure 1 so that ridge lines on the former chart, drawn through the points of maximum vorticity along latitude circles, generally coincide with trough lines on the latter chart, drawn through points of minimum height along latitude circles. When used in conjunction with the mean circulation at 700 mb. (fig. 1) and sea level (Chart XI), figure 3 may be of assistance in delineating the prevailing tracks of migratory cyclones and anticyclones, since Kuo [2] has shown that (on daily maps at least) cyclonic vortices should tend to be driven toward regions of higher absolute vorticity and anticyclonic vortices toward regions of lower absolute vorticity.

For example, Chart X shows that there were two principal tracks of cyclones during the month, one from the Gulf of Alaska along the border between the United States and Canada through Labrador to Iceland, and the other from the southern half of the Great Plains through the Great Lakes and the St. Lawrence Valley to Iceland. Both paths correspond in most respects to the axes of maximum vorticity, except that the cyclone track is displaced slightly to the south of the vorticity maximum in western North America and slightly to the east in

[1] Numerical values of vorticity were computed by means of a simple method to be described in a forthcoming report by E. J. Aubert of the Extended Forecast Section of the U. S. Weather Bureau.

[2] See Charts I–XV following p. 26 for analyzed climatological data for the month.

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eastern North America. These displacements are reflected in corresponding differences in the location of the mean troughs at sea level and 700 mb. and can be attributed to the normal horizontal temperature gradient. It is noteworthy that several cyclones in the eastern Pacific and western North America crossed the 700-mb. contours in the direction of higher height, while the track of nearly all storms in eastern North America and the western Atlantic was across the mean contours toward lower height, but in both cases the crossings were toward higher absolute vorticity.

The anticyclone tracks (Chart IX) are more diffuse than the tracks of cyclones, and it is difficult to delineate the principal paths. Nevertheless, the tracks are clustered in three main regions, the southeast Pacific, northwest Canada, and the southeast United States. Each of these seats of anticyclonic activity was characterized by the presence of mean centers of high pressure at sea level and anticyclonic vorticity at 700 mb. On the other hand, areas of low pressure and cyclonic vorticity in the Gulf of Alaska, north Atlantic, and eastern Canada were notably free of anticyclonic activity. It may also be significant that the anticyclone tracks crossed the mean 700-mb. flow toward regions of lower absolute vorticity in both western North America where they moved mainly southward, and eastern North America and the Atlantic, where they moved mostly eastward.

THE WEATHER

The circulation features discussed above were reflected in this month's weather in the United States. Along the principal cyclone track in the lower Mississippi and Ohio Valleys and the Northeast, just to the east of both the axis of maximum cyclonic vorticity and the mean troughs at sea level and aloft, precipitation generally totaled more than four inches (Chart II) and exceeded the seasonal normal (Chart III, A and B). Much of this precipitation was in the form of snow (Chart IV) which fell in greater than normal quantity (Chart V, A). In addition, average cloudiness in these areas exceeded 60 percent (Chart VI) as well as the seasonal normal (Chart VII, A), sunshine was less than half of the maximum possible (Chart VII, B), and there was less solar radiation than in adjacent regions (trough in isopleths of Chart VIII). Generally similar conditions prevailed in the northwestern quarter of the country, along the principal cyclone track from the Gulf of Alaska, but the various charts present a more irregular appearance in that area because of mountain effects. Precipitation and cloudiness were also excessive in a zonal band extending from Colorado and northern New Mexico eastward to Missouri and Arkansas, as several old disturbances entering the country from the Pacific regenerated in this area (Chart X). This cyclogenesis was favored by topography and the proximity of a mean trough at sea level (Chart XI), cyclonic vorticity at 700 mb. (fig. 2), and a large horizontal temperature gradient (Chart I) with below normal temperatures in the northern and western Plains and above normal temperatures to the south and east (Chart I, inset). As a result of this temperature distribution, snowfall was deficient in the eastern part of the area but excessive in the west (Chart V, A).

In regions of high pressure at sea level and anticyclonic vorticity at 700 mb. the weather elements were generally opposite in character from that discussed above. For example, in the Southeast, where daily anticyclones were frequent and cyclones almost completely absent, precipitation, snowfall, and cloudiness were well below normal, while sunshine and solar radiation were abundant. Likewise in part of the Great Basin precipitation and snowfall were deficient. However, cloudiness was excessive in this area and most of the clouds were probably of the stratiform type formed through stagnation and cooling of Pacific air transported by stronger-than-normal westerlies at 700 mb. (fig. 1). Precipitation and cloudiness were also below seasonal normals in most of Texas and in parts of the northern Plains. In portions of these regions no precipitation at all was recorded during the entire month (Chart II). The drought in Texas was due primarily to the "rain shadow effect" as the State was just south of the strongest belt of westerlies at 700 mb. as well as the principal cyclone track at sea level. Dry weather in the northern Plains was accompanied by anticyclonic conditions at sea level, as attested by the anticyclone tracks (Chart IX) and the presence of both a pronounced mean ridge (Chart XI) and positive pressure anomalies (Chart XI, inset).

The surface temperature anomaly observed in the United States during January 1951 (Chart I, inset) reflected the near-normal character of the 700-mb. circulation for the month (fig. 1). The Northeast was the only large area whose average temperature departed from normal by more than 4° F. This district was abnormally warm primarily because its mean air flow was from a southerly direction relative to normal at both sea level (Chart XI, inset) and 700 mb. In addition 700-mb. heights were somewhat above the seasonal normal. Similar conditions were associated with the warm weather observed in most of the southern and eastern portions of the country. West of the Continental Divide most temperatures were slightly above normal because of the dominance of mild Pacific air transported by stronger-than-normal westerlies at 700 mb. These positive temperature anomalies were larger in the South, where 700-mb. heights were above normal, than in the North, where negative height anomalies were observed.

The only extensive areas with below normal temperatures were the northern and western Plains where 700-mb. heights were generally below normal. Cold polar continental air was carried into these regions by several anticyclones which moved south from a mean High in northwest Canada, at the center of which sea level pressure was 7 mb. above normal (Chart XI, inset). However, the westerlies aloft were stronger than normal (fig. 1) so that frequent foehn warming alternated with the polar outbreaks and caused temperatures to average above normal in the lower and western parts of the Missouri Valley. The most extreme example of this occurred during the last week of the month at Goodland, Kans., where the temperature dropped from 79° F. on the 26th to 3° F. on the 27th, or a 76° fall in 18 hours. (See article by Miller and Gould on following pages for a detailed description of this cold wave.)

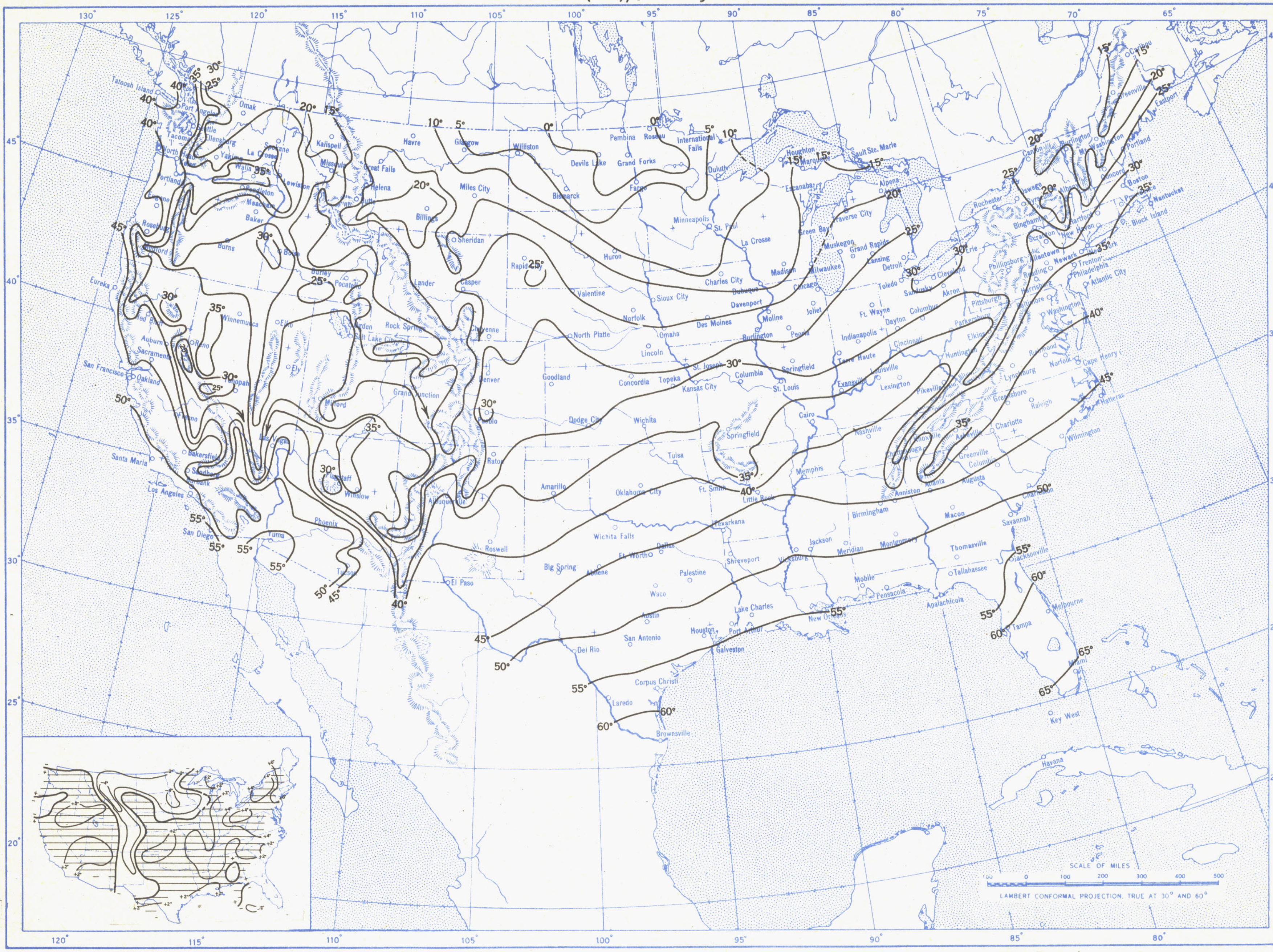
REFERENCES

1. S. Petterssen and J. M. Austin, "Fronts and Frontogenesis in Relation to Vorticity", *Papers in Physical Oceanography and Meteorology*, Massachusetts Institute of Technology and Woods Hole Oceanographic Institution, vol. 7, No. 2, 1942.
2. H. Kuo, "The Motion of Atmospheric Vortices and the General Circulation", *Journal of Meteorology*, vol. 7, No. 4, Aug. 1950, p. 247–258.

NOTICE OF CHANGE IN CLIMATOLOGICAL CHARTS

The charts showing weather data for the month which appear at the back of each issue of the Review have been revised and augmented effective with this issue. Most of the maps showing departures of the weather elements from normal have been enlarged and new maps showing percentages of normal amounts of precipitation, snowfall, and cloudiness have been added. Another new chart giving monthly solar radiation data has been inserted. The former Chart IV "Percentage of Clear Sky between Sunrise and Sunset" has been reversed and now appears as Chart VI "Percentage of Cloudiness between Sunrise and Sunset".

Chart I. Average Temperature (°F.) at Surface, January 1951. Inset: Departure of Average Temperature from Normal (°F.), January 1951.

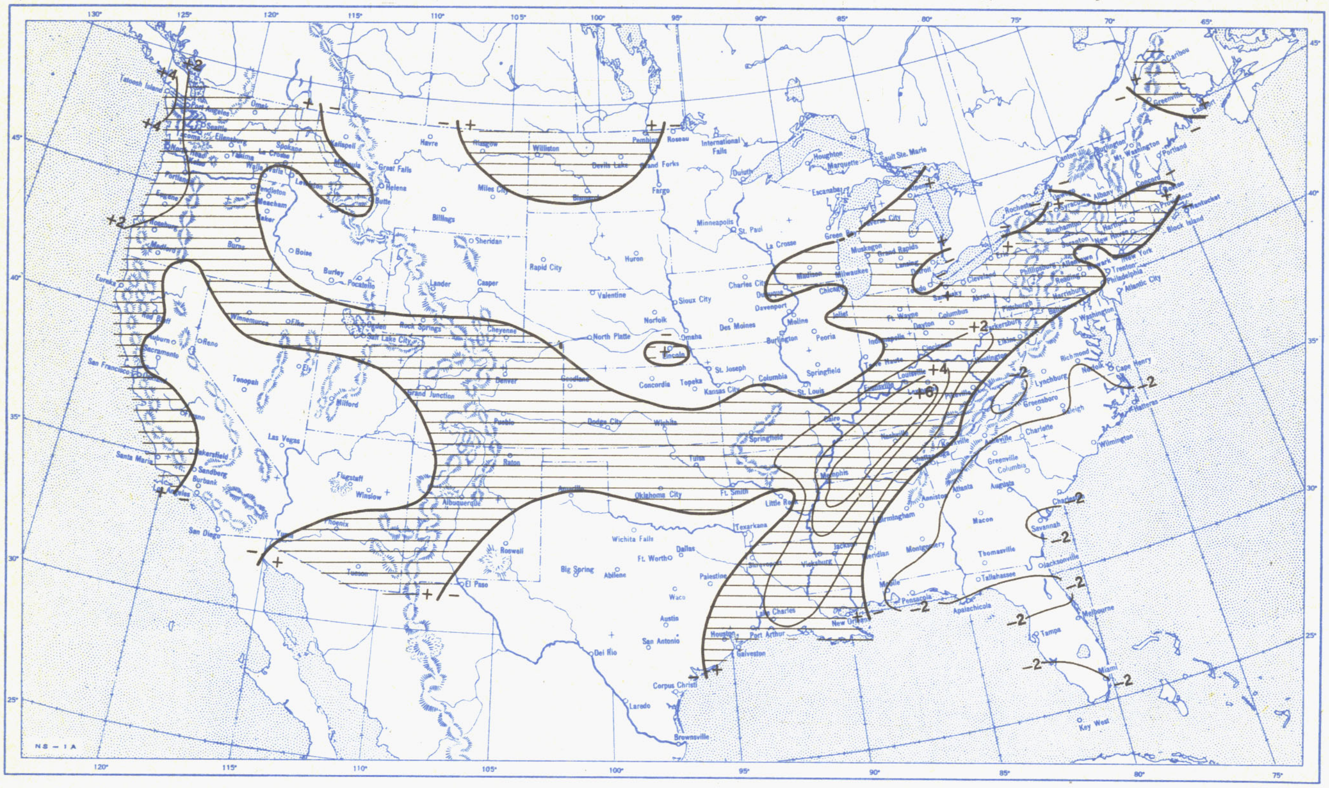


Based on reports from 800 Weather Bureau and cooperative stations. The monthly average is half the sum of the monthly average maximum and monthly average minimum, which are the average of the daily maxima and daily minima, respectively. Normal average monthly temperatures are computed for Weather Bureau stations having at least 10 years of record.

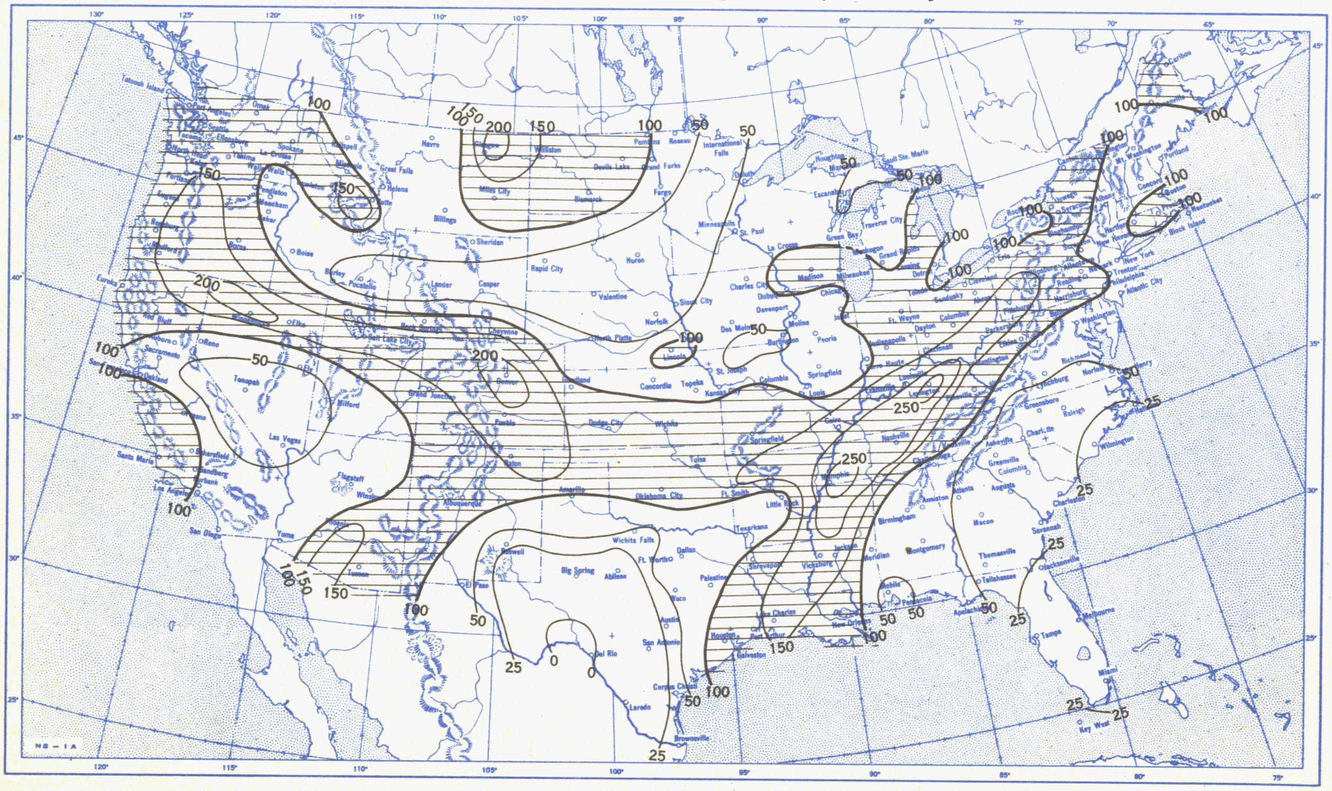
Chart II. Total Precipitation (Inches), January 1951.

Based on daily precipitation records at 800 Weather Bureau and cooperative stations.

Chart III. A. Departure of Precipitation from Normal (Inches), January 1951.

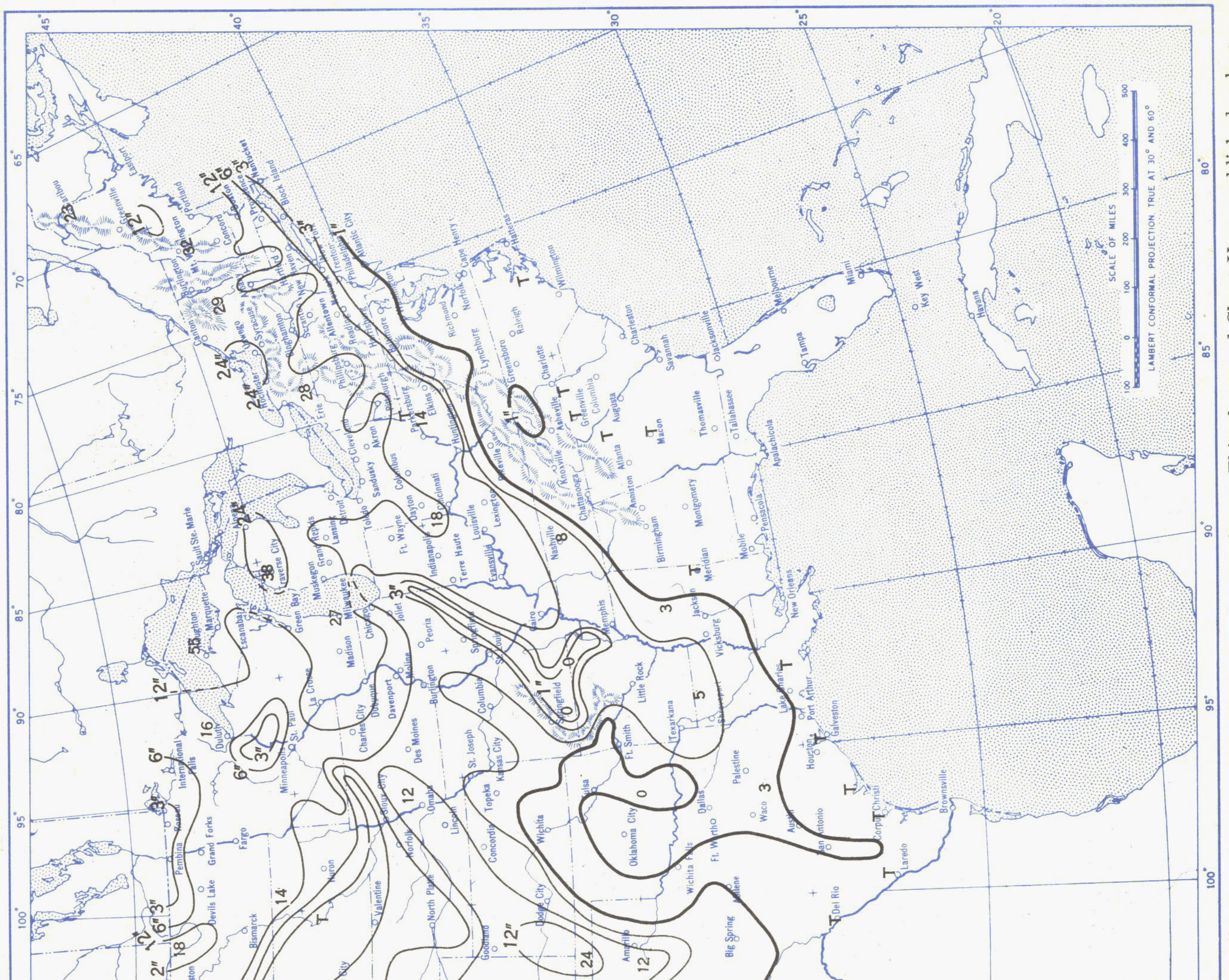


B. Percentage of Normal Precipitation, January 1951.



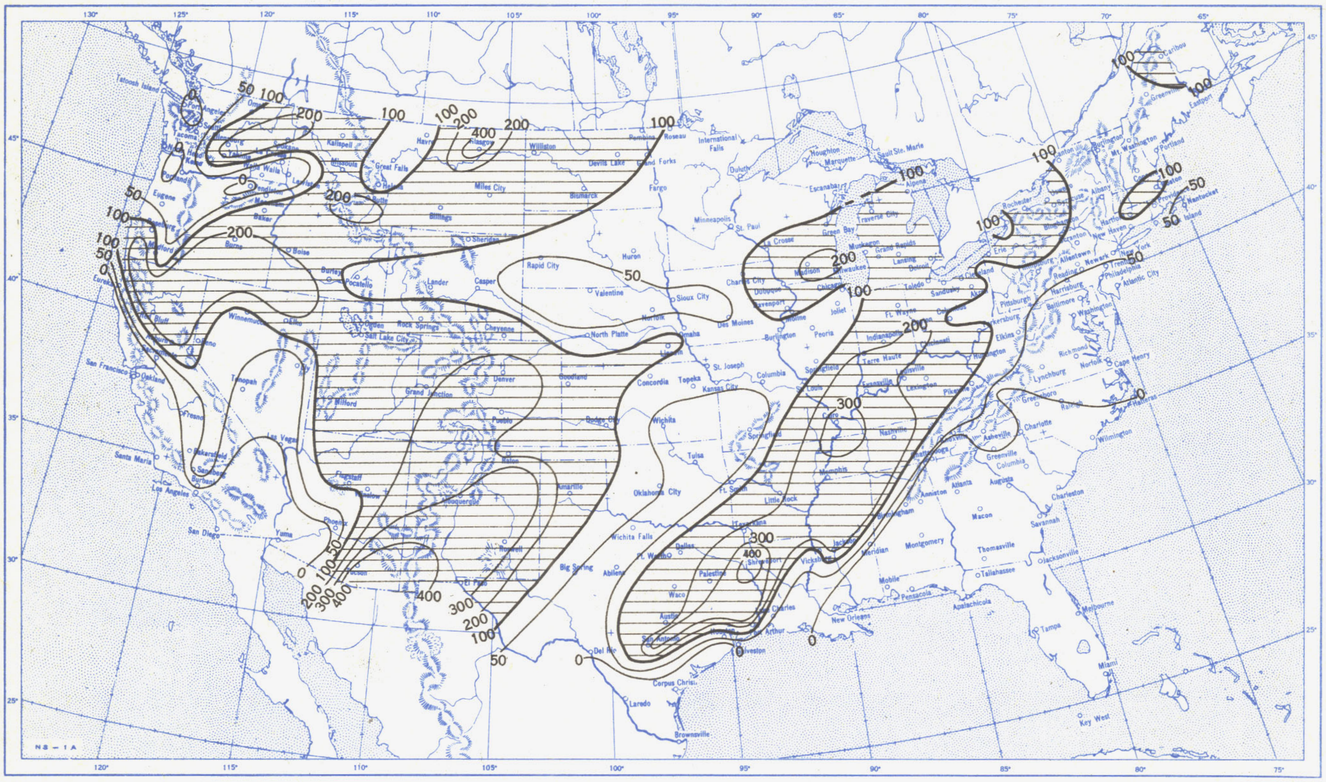
Normal monthly precipitation amounts are computed for stations having at least 10 years of record.

Chart IV. Total Snowfall (Inches), January 1951.

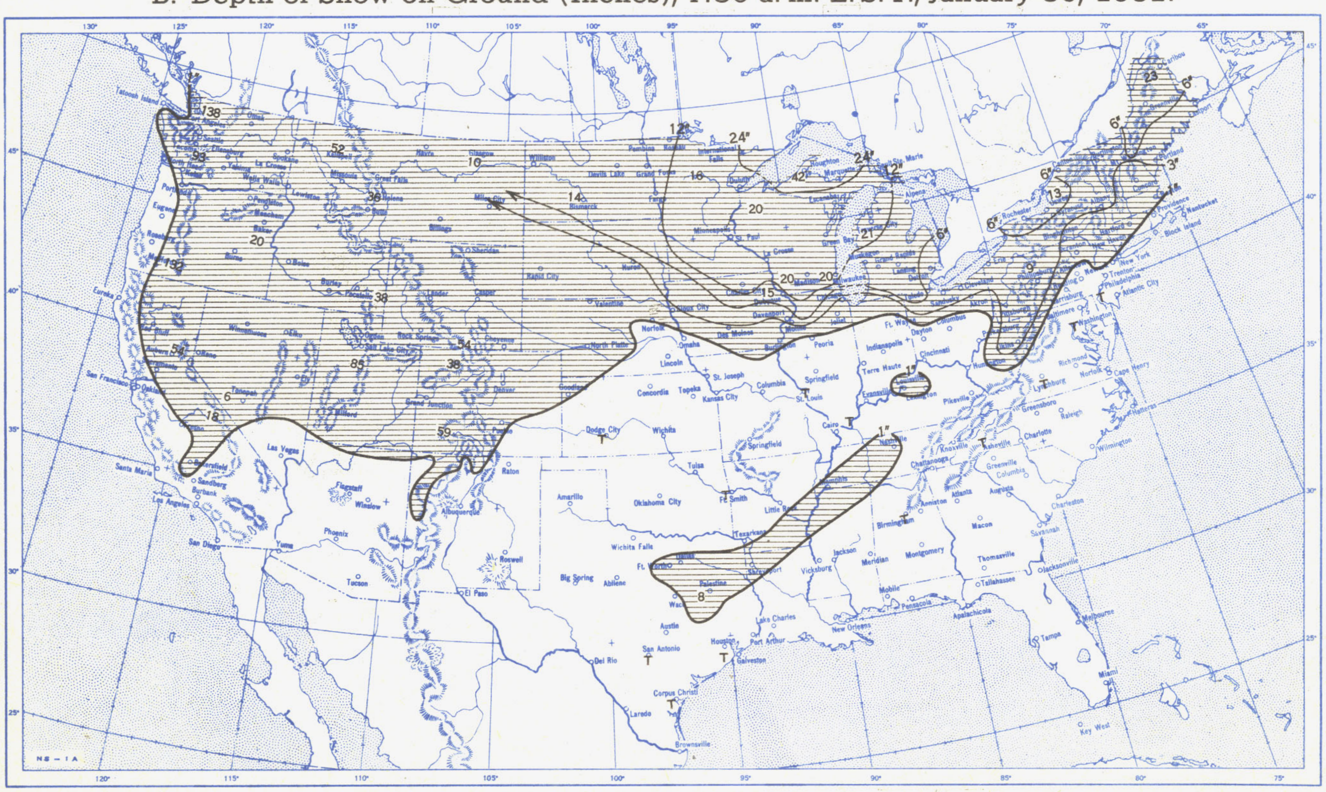


This is the total of unmelted snowfall recorded during the month at Weather Bureau and cooperative stations. This chart and Chart V are published only for the months of November through April although of course there is some snow at higher elevations, particularly in the far West, earlier and later in the year.

Chart V. A. Percentage of Normal Snowfall, January 1951.

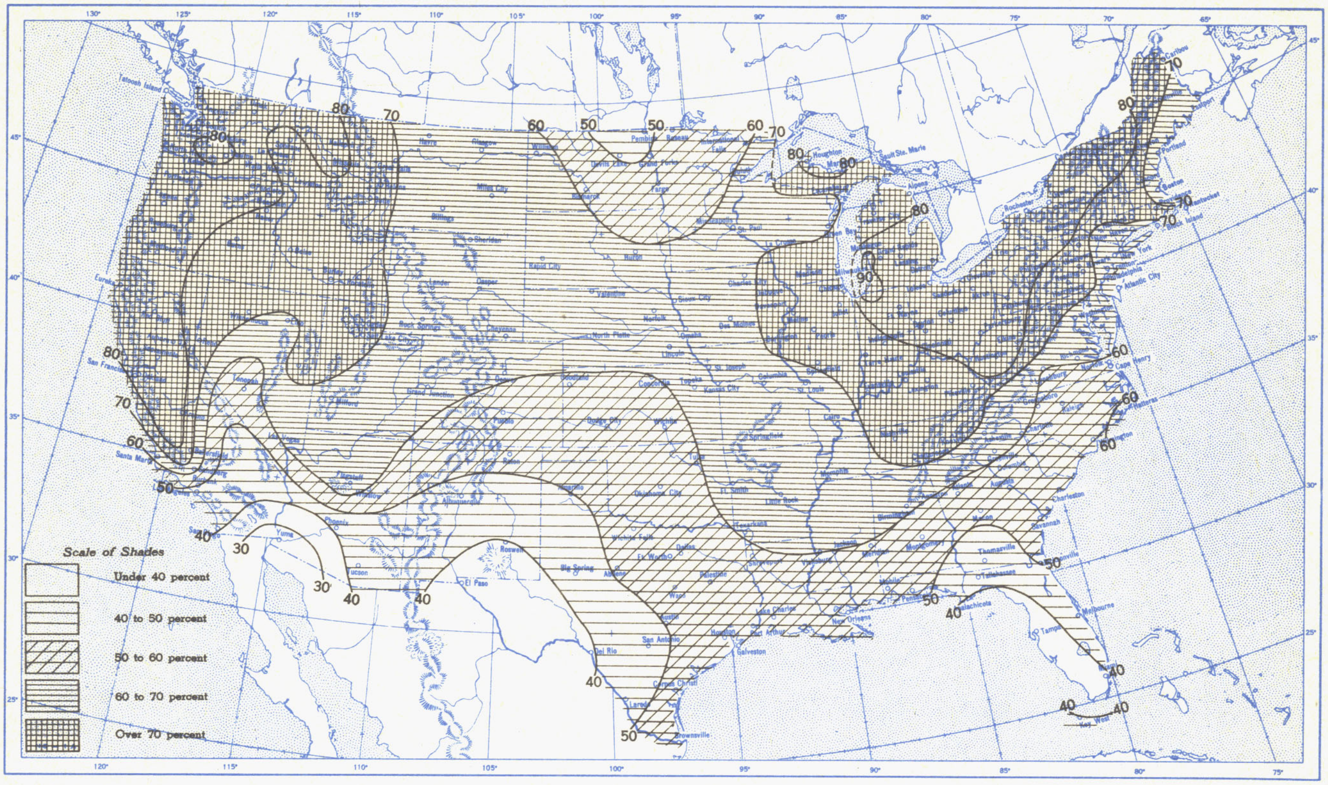


B. Depth of Snow on Ground (Inches), 7:30 a. m. E. S. T., January 30, 1951.

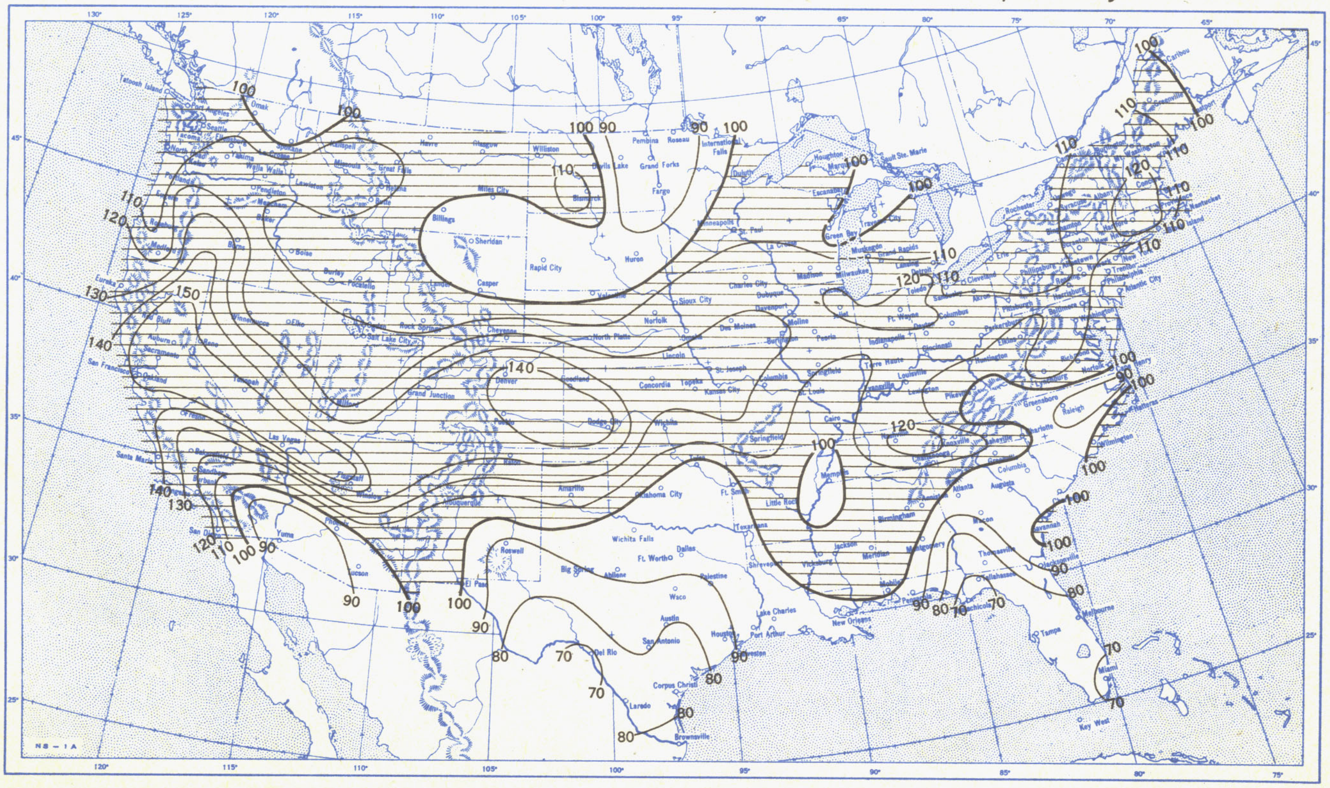


A. Amount of normal monthly snowfall is computed for Weather Bureau stations having at least 10 years of record. B. shows depth currently on ground at 7:30 a. m. E. S. T., of the Tuesday nearest the end of the month. It is based on reports from Weather Bureau and cooperative stations. Dashed line shows greatest southern extent of snowcover during month.

Chart VI. A. Percentage of Sky Cover Between Sunrise and Sunset, January 1951.

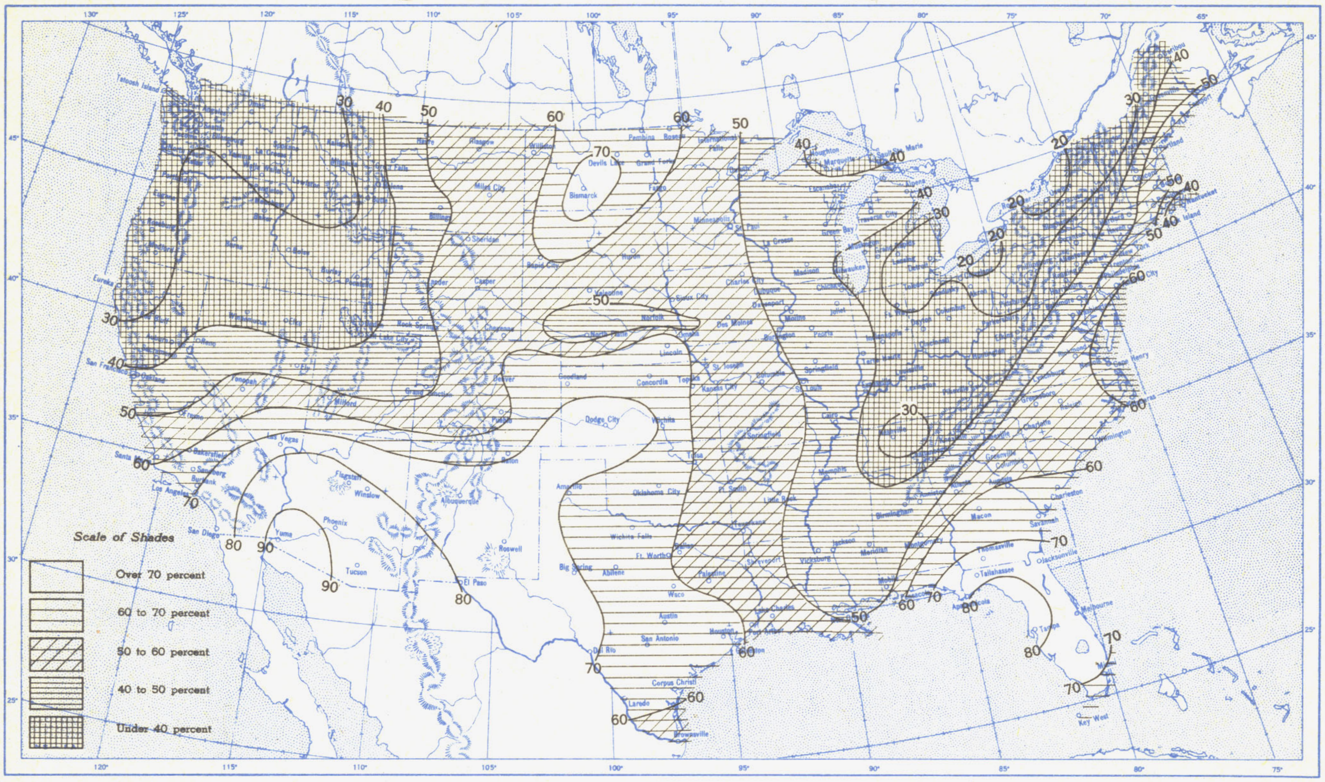


B. Percentage of Normal Sky Cover between Sunrise and Sunset, January 1951.

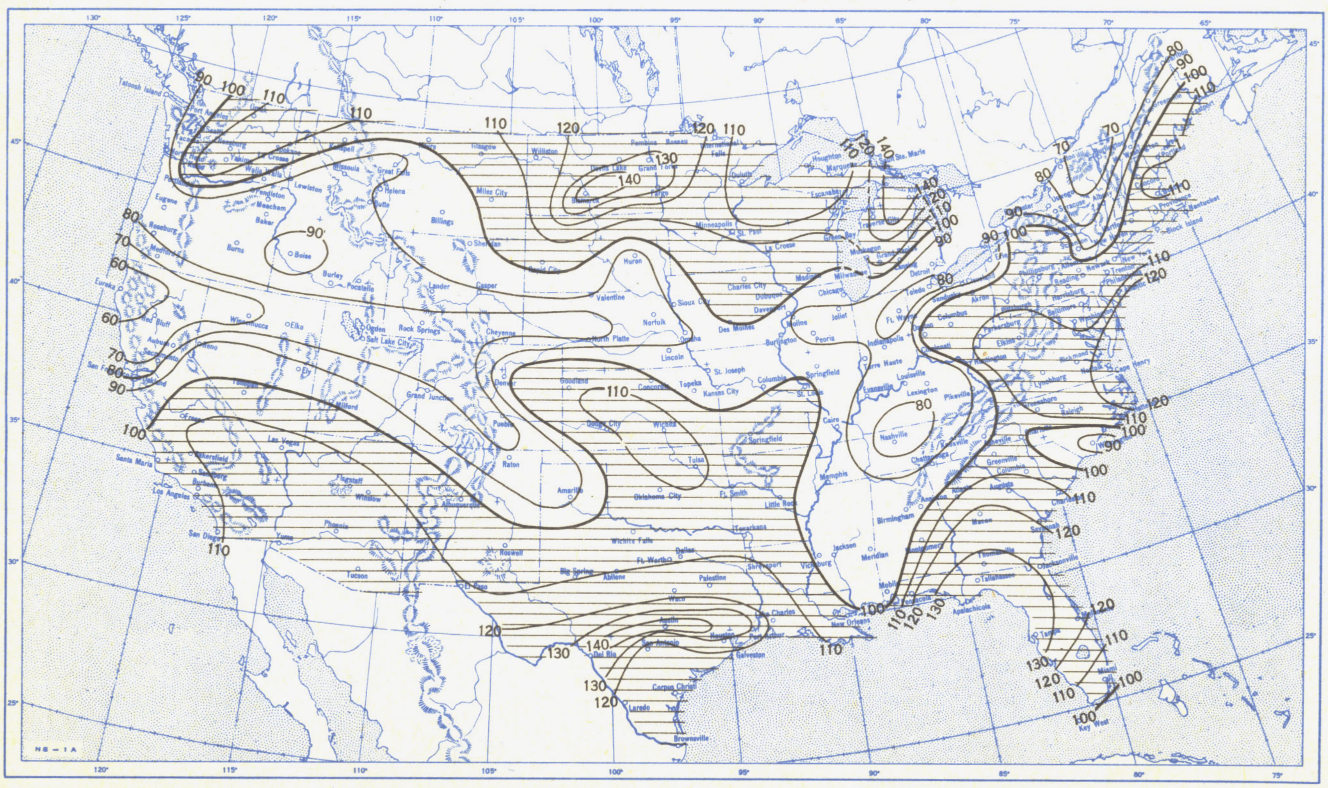


A. In addition to cloudiness, sky cover includes obscuration of the sky by fog, smoke, snow, etc. Chart based on visual observations made hourly at Weather Bureau stations and averaged over the month. B. Computations of normal amount of sky cover are made for stations having at least 10 years of record.

Chart VII. A. Percentage of Possible Sunshine, January 1951.



B. Percentage of Normal Sunshine, January 1951.



A. Computed from total number of hours of observed sunshine in relation to total number of possible hours of sunshine during month. B. Normals are computed for stations having at least 10 years of record.

Chart VIII. Average Daily Values of Solar Radiation, Direct + Diffuse, January 1951. Inset: Percentage of Normal Average Daily Solar Radiation, January 1951.

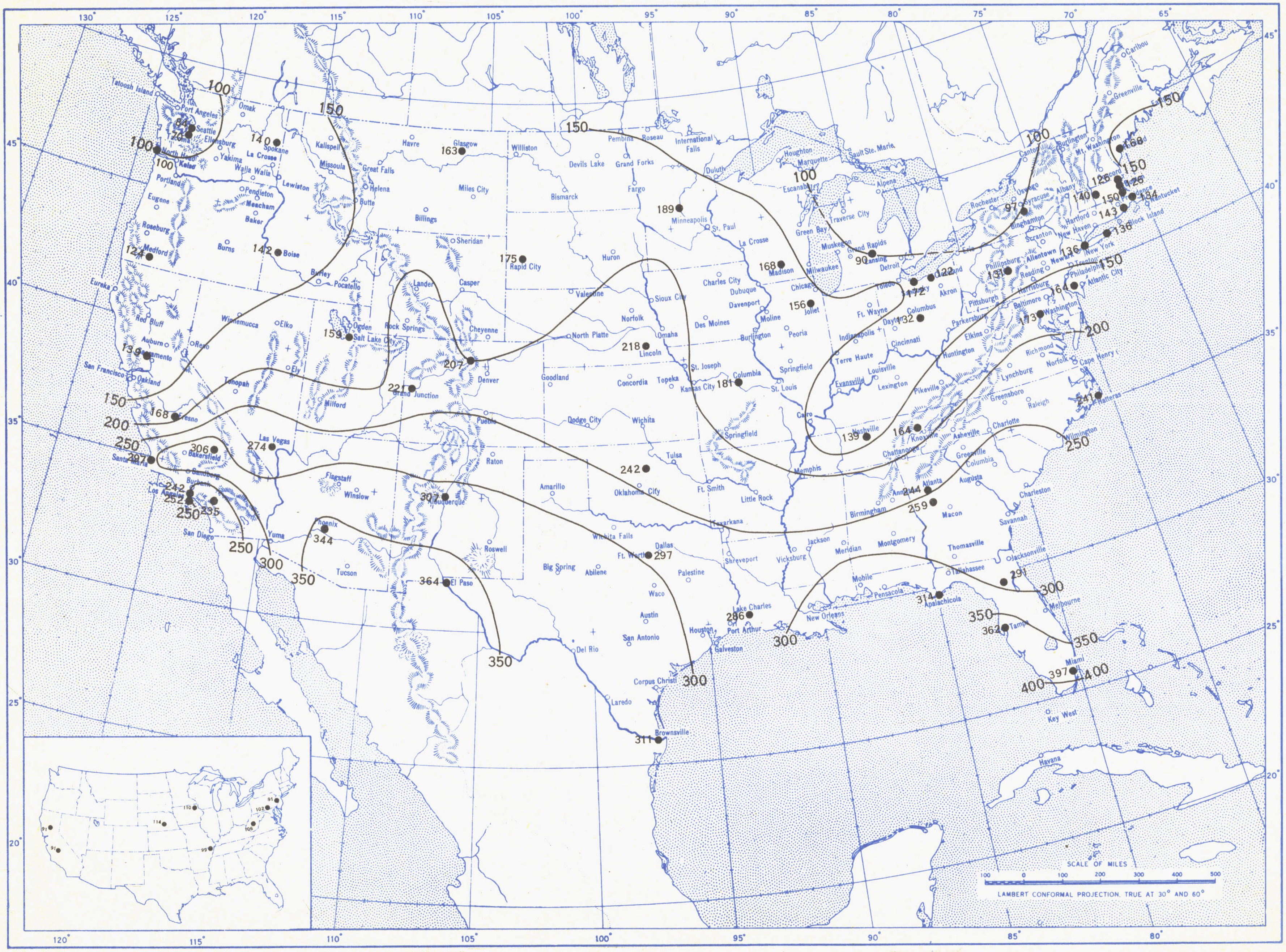
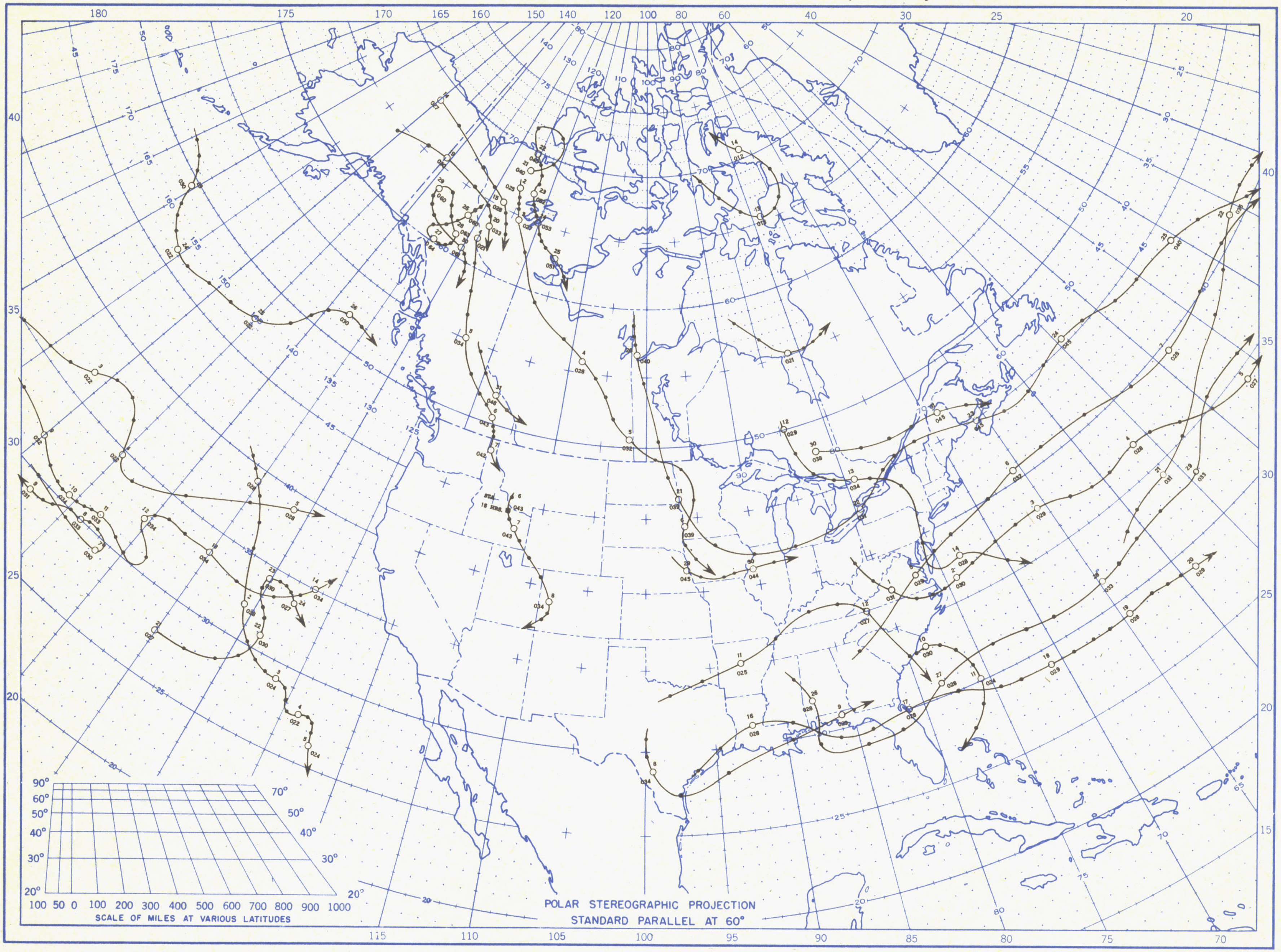


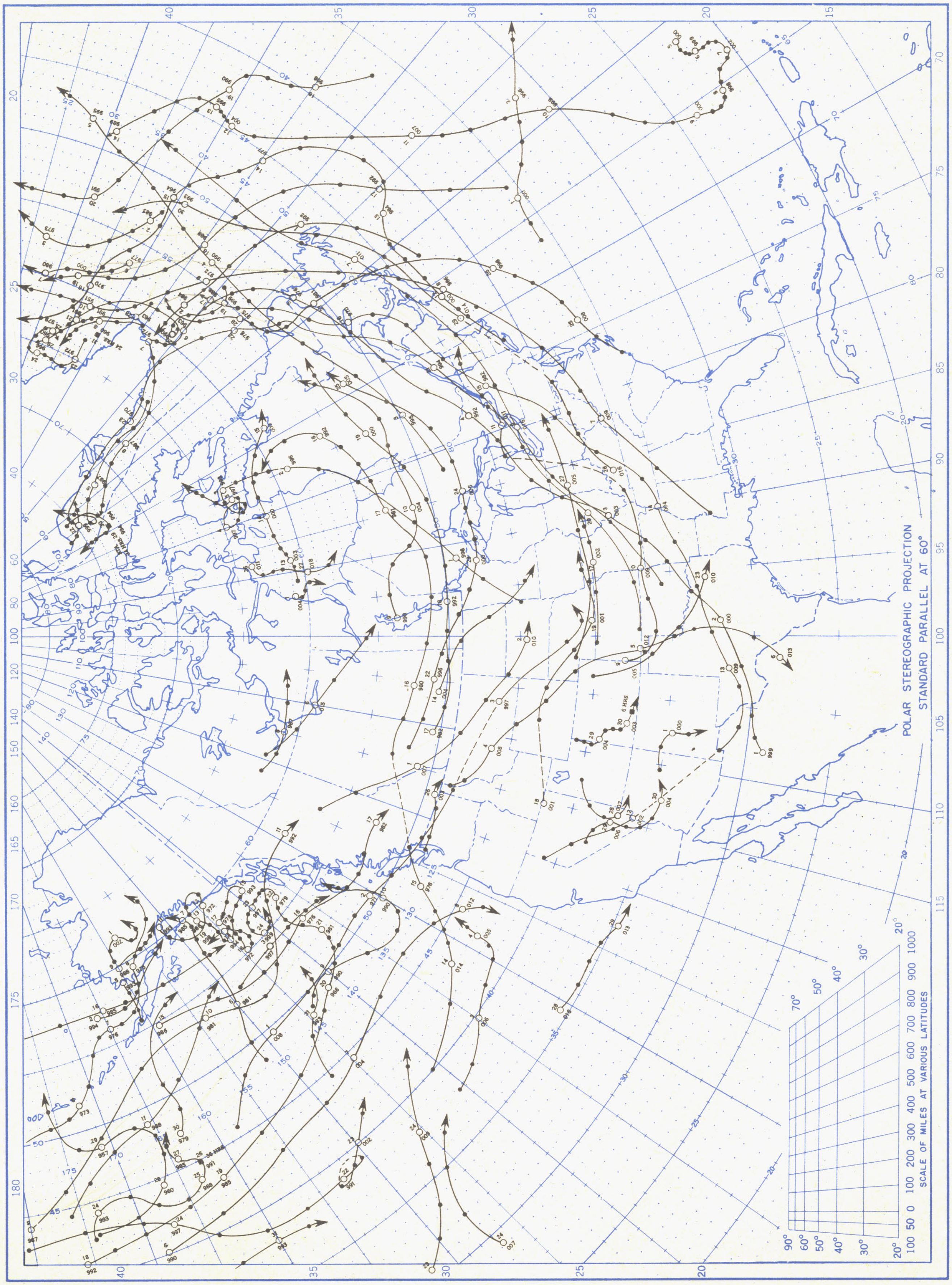
Chart shows mean daily solar radiation, direct + diffuse, received on a horizontal surface in langleys (1 langley = 1 gm. cal. cm. $^{-2}$). Basic data for isolines are shown on chart. Further estimates obtained from supplementary data for which limits of accuracy are wider than for those data shown. Normals are computed for stations having at least 9 years of record.

Chart IX. Tracks of Centers of Anticyclones at Sea Level, January 1951



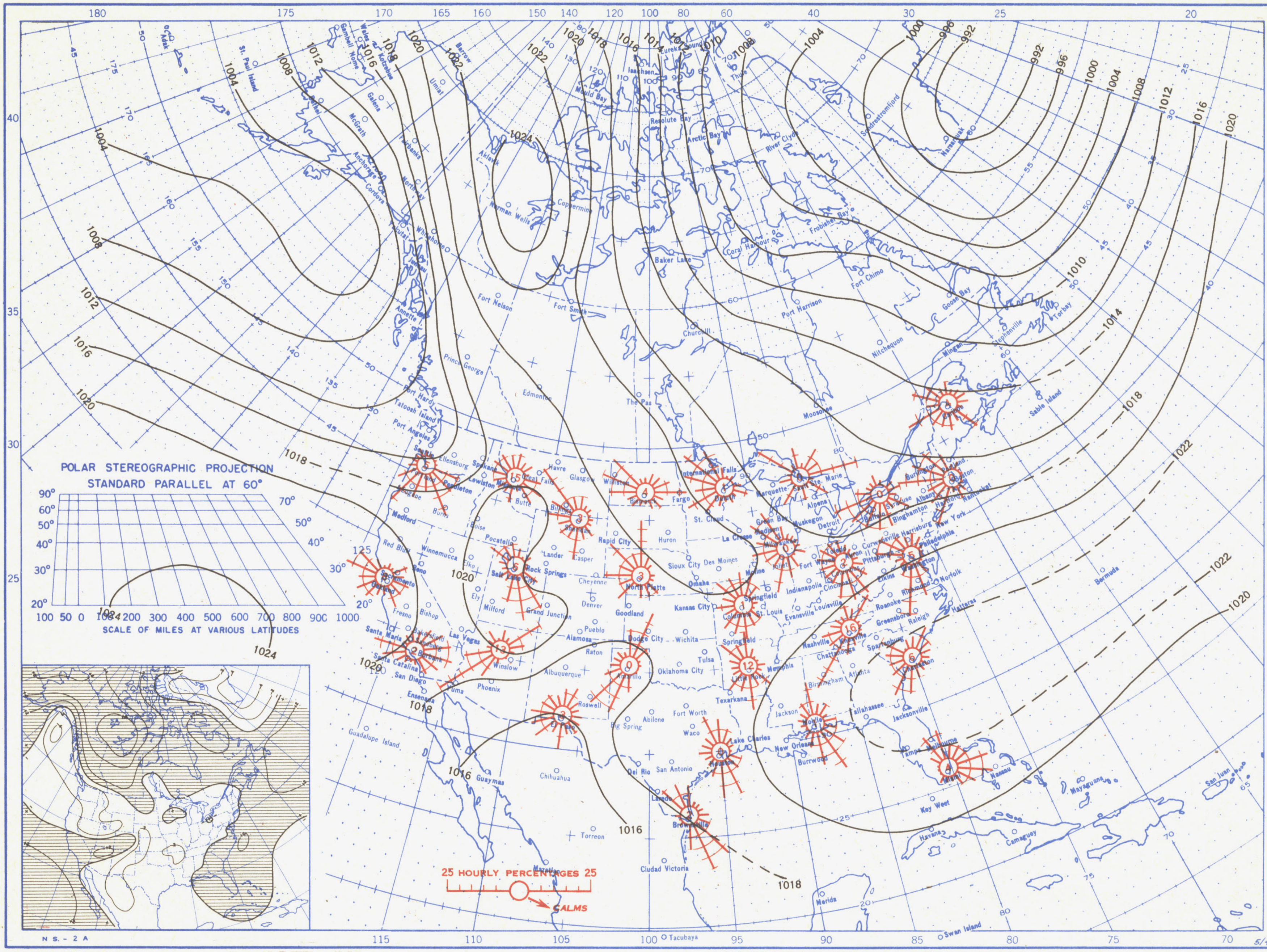
Circle indicates position of center at 7:30 a. m. E. S. T. Figure above circle indicates date, figure below, pressure to nearest millibar. Dots indicate intervening 6-hourly positions. Squares indicate position of stationary center for period shown. Dashed line in track indicates reformation at new position. Only those centers which could be identified for 24 hours or more are included.

Chart X. Tracks of Centers of Cyclones at Sea Level, January, 1951.



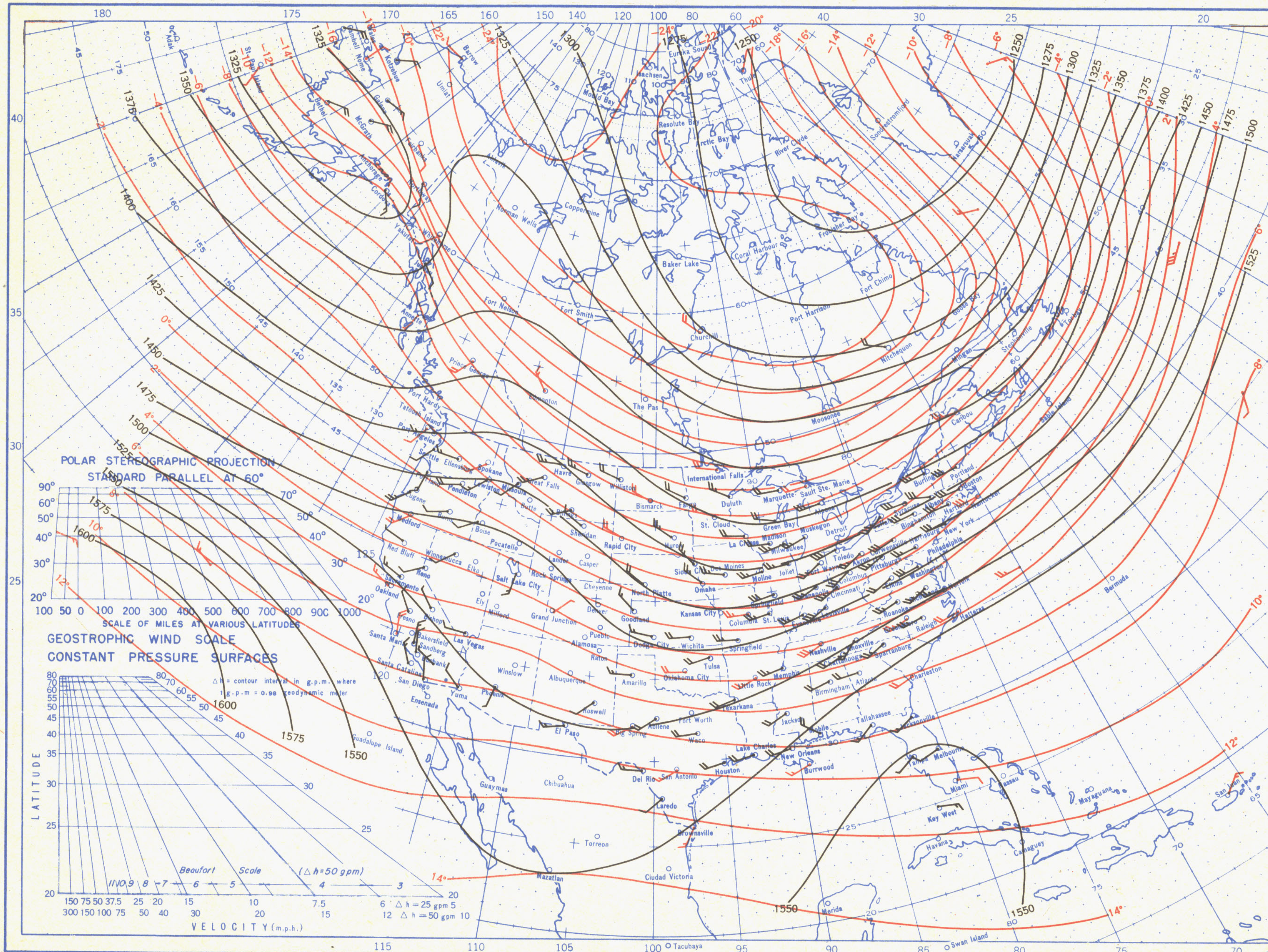
Circle indicates position of center at 7:30 a. m. E. S. T. See Chart IX for explanation of symbols.

Chart XI. Average Sea Level Pressure (mb.) and Surface Windroses, January 1951. Inset: Departure of Average Pressure (mb.) from Normal, January 1951.



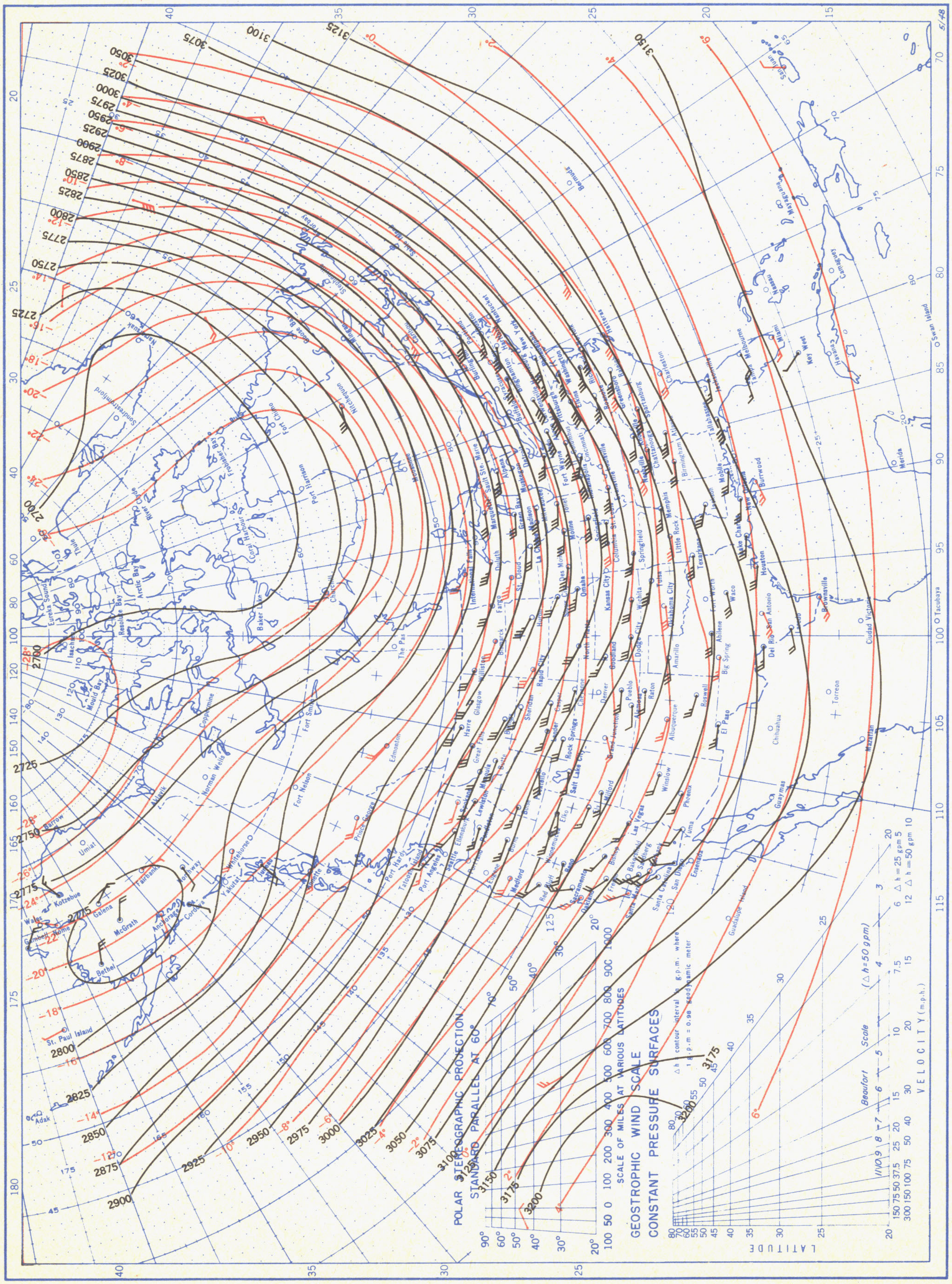
Average sea level pressures are obtained from the averages of the 7:30 a. m. and 7:30 p. m. E. S. T. readings. Windroses show percentage of time wind blew from 16 compass points or was calm during the month. Pressure normals are computed for stations having at least 10 years of record and for 10° intersections in a diamond grid from map readings for 20 years of the Historical Weather Maps, 1899–1939.

Chart XII. Average Dynamic Height in Geopotential Meters (1 g.p.m. = 0.98 dynamic meters) of the 850-mb. Pressure Surface, Average Temperature in °C. at 850 mb., and Resultant Winds at 1500 Meters (m.s.l.), January 1951.



Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins taken at 0300 G. M. T.

Chart XIII. Average Dynamic Height in Geopotential Meters (1 g.p.m. = 0.98 dynamic meters) of the 700-mb. Pressure Surface, Average Temperature in °C. at 700 mb., and Resultant Winds at 3000 Meters (m.s.l.), January 1951.



Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins taken at 0300 G. M. T.

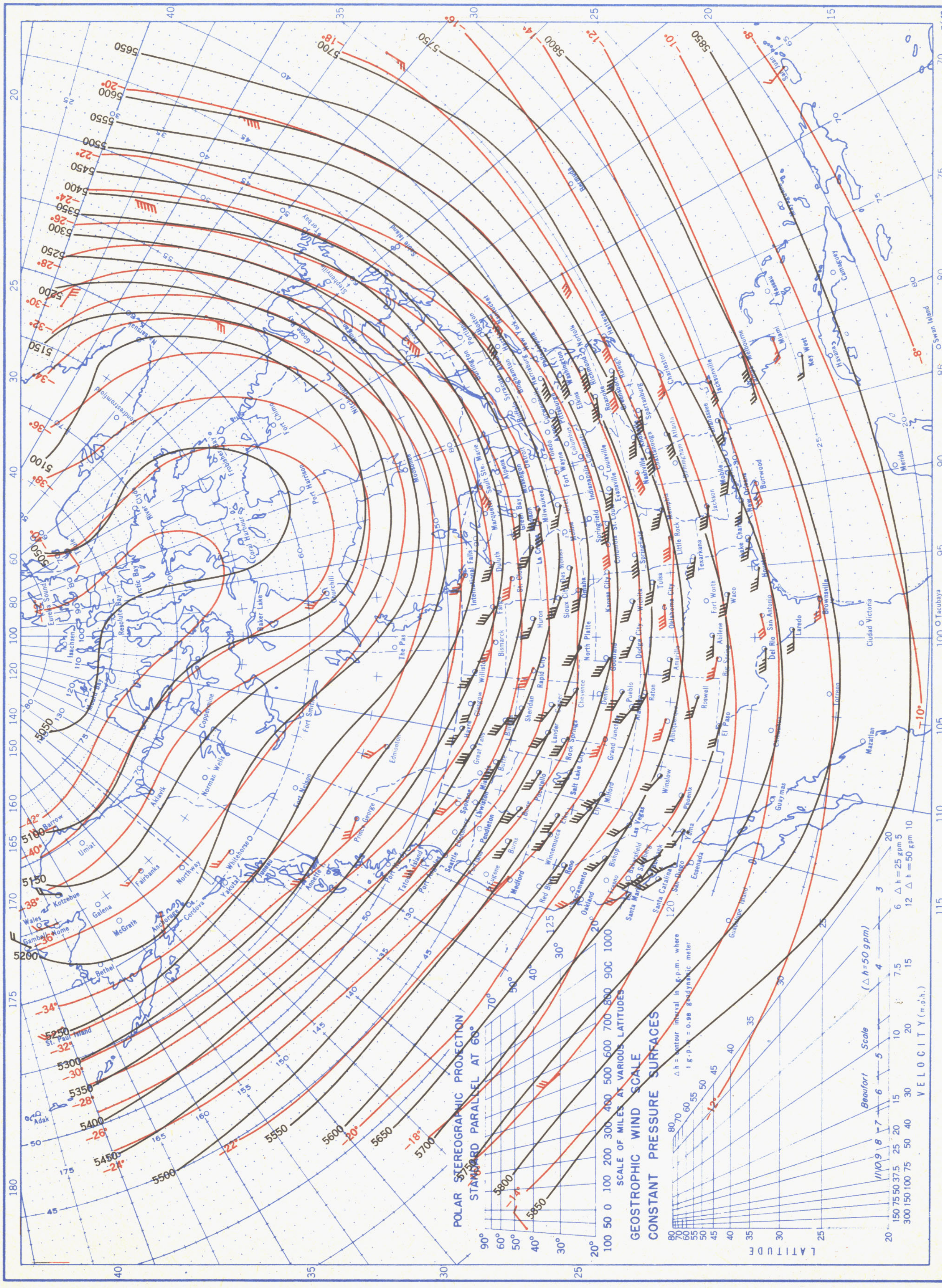
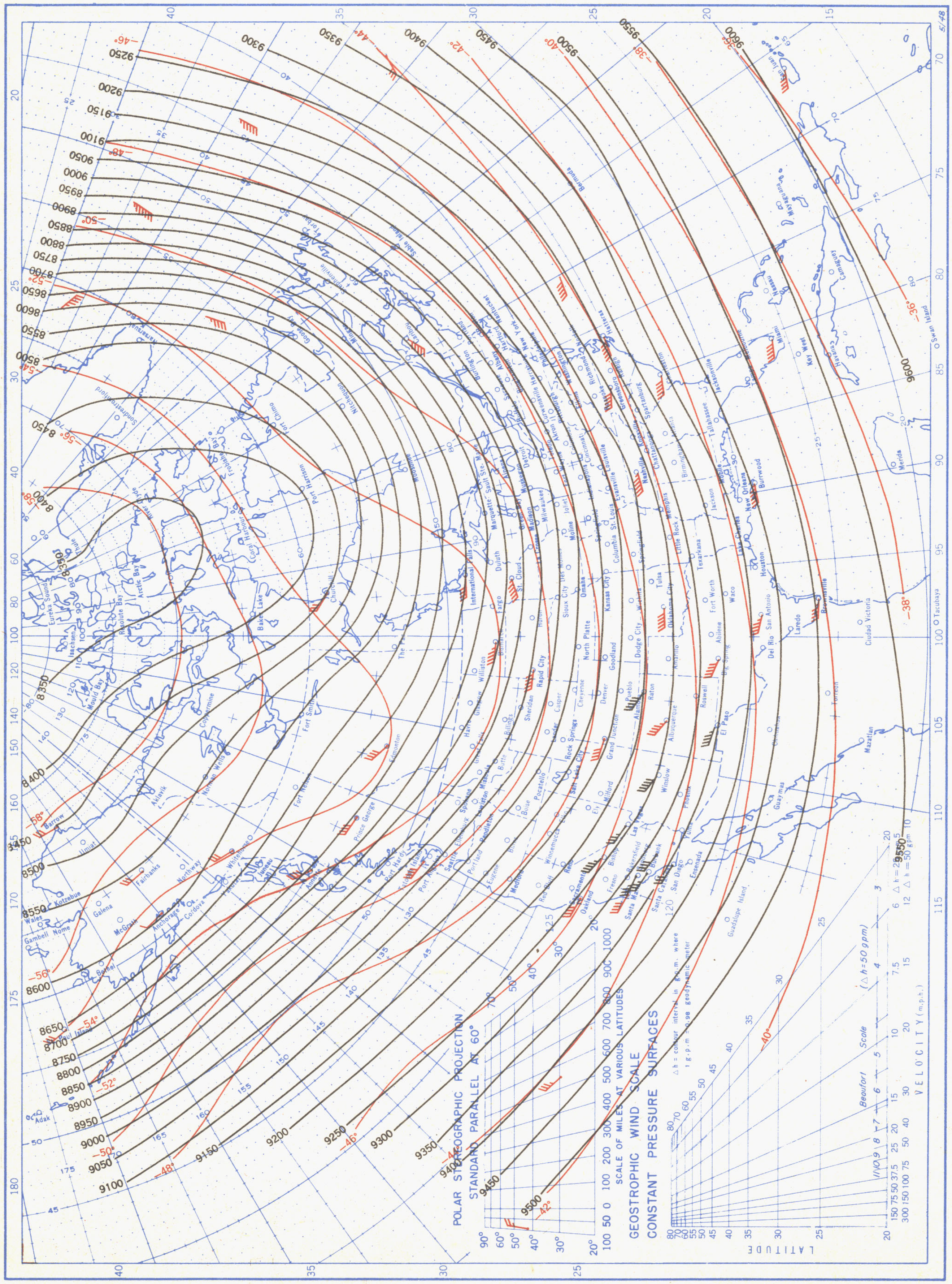


Chart XIV. Average Dynamic Height in Geopotential Meters (1 g.p.m. = 0.98 dynamic meters) of the 500-mb. Pressure Surface, Average Temperature in °C at 500 mb., and Resultant Winds at 5000 Meters (m.s.l.), January 1951.

Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins at 0300 G. M. T.

Chart XV. Average Dynamic Height in Geopotential Meters (1 g.p.m. = 0.98 dynamic meters) of the 300-mb. Pressure Surface, Average Temperature in °C. at 300 mb., and Resultant Winds at 10,000 Meters (m.s.l.), January 1951.



Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins at 0300 G. M. T.